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Current Management of Frontal Sinus Injuries

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1. Introduction

Frontal sinus fractures are relatively uncommon and are usually seen as a part of severe head injuries caused by high-velocity injuries. The management of frontal sinus fractures involves many difficulties since the frontal sinus is situated at the junction between the cranium and the face, and has anatomical features of both. Intracranial involvement should always be anticipated when upper facial trauma is suspected. Often the planning of how to treat frontal sinus fractures must actually be decided during the operation itself, because the fractures may extend more widely than predicted by pre-operative examination. Posterior wall fractures have more complications and a worse clinical outcome than fractures that only involve the anterior wall. Acute and chronic sinusitis, mucocoele, mucopyocoele, osteomyelitis, meningitis, and brain abscess are associated with frontal sinus injury. The purpose of this chapter is to present an overview of the frontal sinus fractures, associated injuries and a rationale for selecting surgical approach to frontal sinus injury.

2. Frontal sinus anatomy

The frontal sinus has a thick strong anterior wall, a thin fragile floor and a posterior wall. Its floor is the roof of the orbit. Its posterior wall forms the anteroinferior portion of the anterior wall of the anterior cranial fossa. Because the superior sagittal sinus lies against the posterior wall of the frontal sinus, it is vulnerable to injury in fracture dislocations of the posterior wall. Fortunately because of the toughness and resiliency of the dura, rupture of the superior sagittal sinus is uncommon, but when it occurs, the patient often dies of uncontrollable hemorrhage [1]. A vertical septum has commonly placed approximately in the center of the frontal sinus. In the case of highly developed orbital ethmoidal cells, the roofs of these cells make up the medial aspect of the frontal sinus floor. The nasofrontal ducts are located on either side of the frontal sinus. The opening of these structures is variable. They usually drain directly into the

frontal recess, but they also may drain above the ethmoid infundibulum, into it or above the ethmoid bulla.

The frontal sinus is lined with pseudostratified ciliated columnar epithelium. The main source of blood supply to the frontal sinus is a diploic branch of the supraorbital artery [2]. The frontal sinus also receives some blood supply from branches of the anterior ethmoidal artery [1]. External venous drainage is through the angular and anterior facial veins. The deep drainage is through the foramen of Breschet which is located on the posterior wall of the sinus. This structure is responsible for communication with the subdural venous system in the subarachnoid space [1].

3. Frontal sinus fracture

A frontal sinus fracture is a common injury in patients who suffer high-energy trauma from motor vehicle accidents or altercations [3]. The frontal sinus fracture accounts for 5–15% of all fractures of the maxillofacial area [4] and is often associated with neurological deficit and other facial fractures [3]. The involvement of the brain is not uncommon. It has been suggested that more than 80% of the patients with a fracture of both the anterior and the posterior wall have intracranial injuries, such as hemorrhages and cerebral contusions [5]. Pain is a common symptom in conscious patients with a frontal sinus fracture. Lacerations are seen in 50% of patients. About 25% of patients have a visible depression of the forehead [6]. Other possible symptoms are epistaxis, problems with vision, edema and paresthesia of the supraorbital region. Leakage of cerebrospinal fluid, due to damage of the dura, is a common finding [4]. Computed tomography (CT) is the gold standard in diagnosing the degree of involvement of the frontal sinus [3].

4. Diagnosis of frontal sinus fracture

The physical examination of patients with frontal sinus fractures is difficult because of soft tissue swelling. The detection of cerebrospinal fluid rhinorrhea which indicates a posterior table injury with a dural tear is an important preoperative finding. CSF rhinorrhea is rarely detected because the fluid drains from the oropharynx. The surgeon should attempt to obtain a sample of this by having the patient lean forward to allow drainage from the nose and test the fluid for glucose or β -2 transferrin to confirm the diagnosis. Other signs of frontal sinus fracture include supraorbital nerve anesthesia and a depressed frontal region [7]. The most common associated finding is a laceration of the supraorbital ridge (Figure 1), glabella, or lower forehead [8]. These lacerations are often extensive and may be contaminated by foreign material [9].

Plain skull radiographs including the Caldwell and lateral views are occasionally used. Sinus pathology is strongly suspected when the radiograph demonstrates air-fluid levels, a diffusely cloudy sinus, or pneumocephalus. Accurate serial 1.5 mm cuts computed tomography (CT)



Figure 1. Left: A 52-year-old patient who has facial laceration due to an industrial accident. Right: CT scan of the same patient reveals both anterior and posterior table fractures of the frontal sinus.

imaging in both the axial (Figure 2) and coronal planes should be obtained in all cases to determine the degree of injury to the anterior and posterior tables and nasofrontal ducts [10]. The CT scan allows for visualization of the brain, face, and orbits as well, which is often necessary because of the high rate of associated injuries [9].

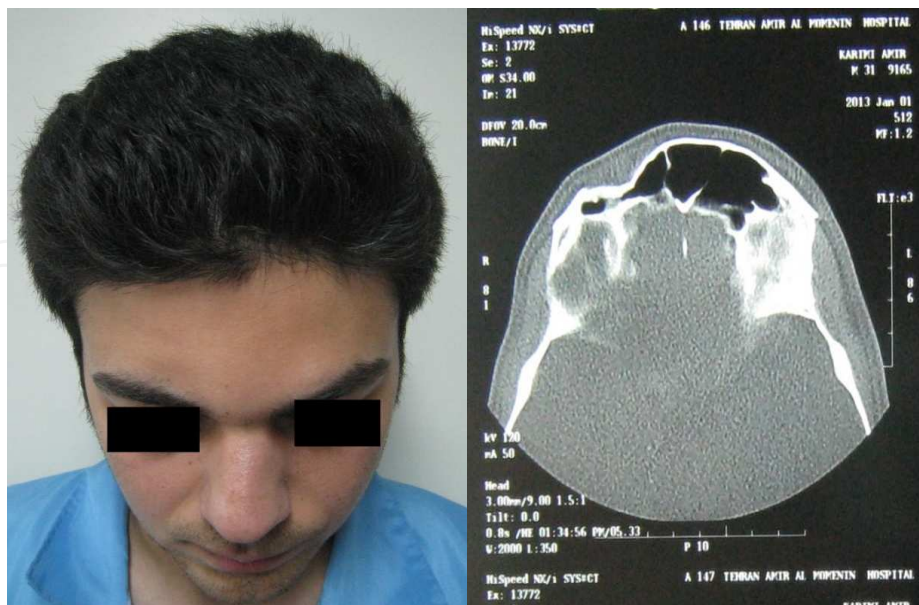


Figure 2. Left: A 26-year-old patient who had a motor vehicle accident with blunt trauma to the head. Note that there is no sign of depression or asymmetry of the face. Right: CT scan of the same patient reveals frontal sinus fracture with severe bone depression.

5. Treatment modalities

Isolation of the neurocranium, cessation of any CSF leak, prevention of early and delayed postoperative complications and restoration of the preoperative facial aesthetics are the aims of treatment of frontal sinus fractures. The integrity of the posterior wall and/or involvement of the nasofrontal duct are the factors influencing treatment. The integrity of the posterior wall is the main factor for the separation of the intracranial contents from the outer environment. The nasofrontal duct involvement is the decisive factor for the potential dysfunction of the sinus mucosa. Closed fractures of the anterior wall of the frontal sinus without displacement do not require surgical treatment and only observation is required. The treatment of depressed fracture of the anterior wall without involvement of the nasofrontal duct is simple elevation of the fracture and plate fixation. However, if the duct is involved, the treatment should include the obliteration of the sinus cavity after the sealing of the injured duct. In this way the frontal sinus is treated as an isolated cavity precluding any potential mucosal regrowth from the nasal epithelium. If the posterior wall is involved the determinant of successful management of the frontal sinus fracture is removal of the displaced bony fragments of the posterior sinus wall, restoration of the dural integrity and complete isolation of the brain from potential communication with the nose through the injured frontal sinus and cranialization of the frontal sinus [11].

6. Surgical approach

The most common approach is the bicoronal flap. It has several advantages including providing the best exposure of the frontal bone and the best cosmetic result in patients without alopecia. Its disadvantages are increased intraoperative blood loss and risk of injury to the frontal branch of the facial nerve. When using this approach, the hair is parted at the anticipated incision site and the tufts of parted hair are brought together and secured with small rubber bands on each side of the incision. Shaving of hair is not necessary. The incision site is infused with local anesthetic with 1:100,000 epinephrine in a subgaleal plane. The scalp is then incised from one temporal line to the other through the skin and subcutaneous tissues. A scalpel is used to incise the galea. Once the galea is violated, there will be an obvious separation between the galea and the pericranium. Bleeding from larger vessels should be tied off individually. The application of Raney clips minimizes the risk of bleeding. Finger dissection can then be used to elevate 2 to 3 cm on either sides of the incision, taking care to maintain the integrity of the pericranium. Overlying the temporalis muscle superiorly, the plane of dissection should remain in the loose areolar layer, which is deep to the temporoparietal fascia containing the frontal branch and superficial to the deep temporal fascia. In other areas overlying bone, the flap is raised in a plane immediately superficial to the pericranium. Carrying out the dissection in the correct anatomic plane minimizes the risk of injury to the frontal branch of the facial nerve. At the region of the zygomatic arch, the frontal branch of the facial nerve is most vulnerable to injury. If the dissection is carried within 1 to 2 cm of the arch, the plane of dissection should be one layer deeper in this area and dissection should be just deep to the

superficial layer of the deep temporal fascia [12]. After the soft tissue has been retracted, the pericranium is incised several centimeters superior to the most superior aspect of the frontal sinus and raised inferiorly to a level approximately 1 cm below the inferior extent of the frontal sinus. Other options for incision include the midforehead and the gull wing incisions. These approaches offer decreased operative time, decreased blood loss, and decreased risk of injury to the frontal branch of the facial nerve. However, they also limit exposure, increase the incidence of damage of the ophthalmic branch of the trigeminal nerve, and leave more visible scars [13, 14].

7. Frontal recess fracture

Frontal recess fractures only result in disruption of the frontal sinus outflow tract. Regardless of anterior or posterior table injuries, frontal recess fractures that result in sinus outflow obstruction will require frontal sinus obliteration. Endoscopic frontal sinusotomy has also been described for the management of persistent obstruction. However, endoscopic frontal sinusotomy following frontal recess trauma is technically challenging and should only be considered in reliable patients.

8. Anterior table fracture

A displaced fracture of the anterior table is the most common type of frontal sinus injury [15] which leaves a contour deformity of the forehead. Anterior table fractures involving the nasal-orbital-ethmoidal area or supraorbital rim have a 25% to 50% incidence of nasofrontal duct involvement [16-19]. In general, operative exposure of an anterior table fracture should also include an intraoperative examination of the nasofrontal duct to evaluate for injury. Exposure is best achieved by using a bicoronal incision (Figure 3).

Once the coronal incision has been made and the anterior table exposed, sinusotomy must be planned. One prong of a bayonet forceps is placed inside the sinus to the maximum peripheral extent. The corresponding prong then reflects its position on the external surface of the outer table. A number 701 burr in a high-speed drill marks the perimeter adjacent to the bayonet forceps. After sinus marking is complete, the osteotomy is accomplished using either a drill or oscillating saw [20]. Once the frontal sinus has been entered, cultures are taken of any fluids encountered. At this point, nasofrontal duct patency can be evaluated with the placement of either fluorescein or methylene blue proximally at the ostium located medially at the sinus floor. If there is no evidence of nasofrontal duct obstruction, the fracture fragments should be reduced and fixated (Figure 4).

The severely comminuted anterior table is best repaired with a precontoured plate (Figure 5). If there is significant comminution of the anterior table with bone loss, split calvarial graft is the material of choice to address defects of the anterior table (Figure 6). The use of synthetic

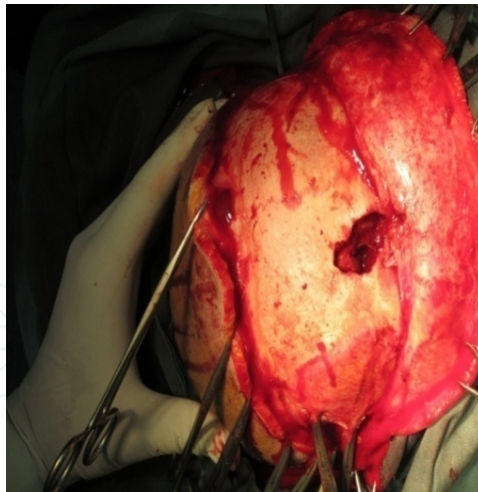


Figure 3. The frontal sinus fracture is approached via bicoronal incision

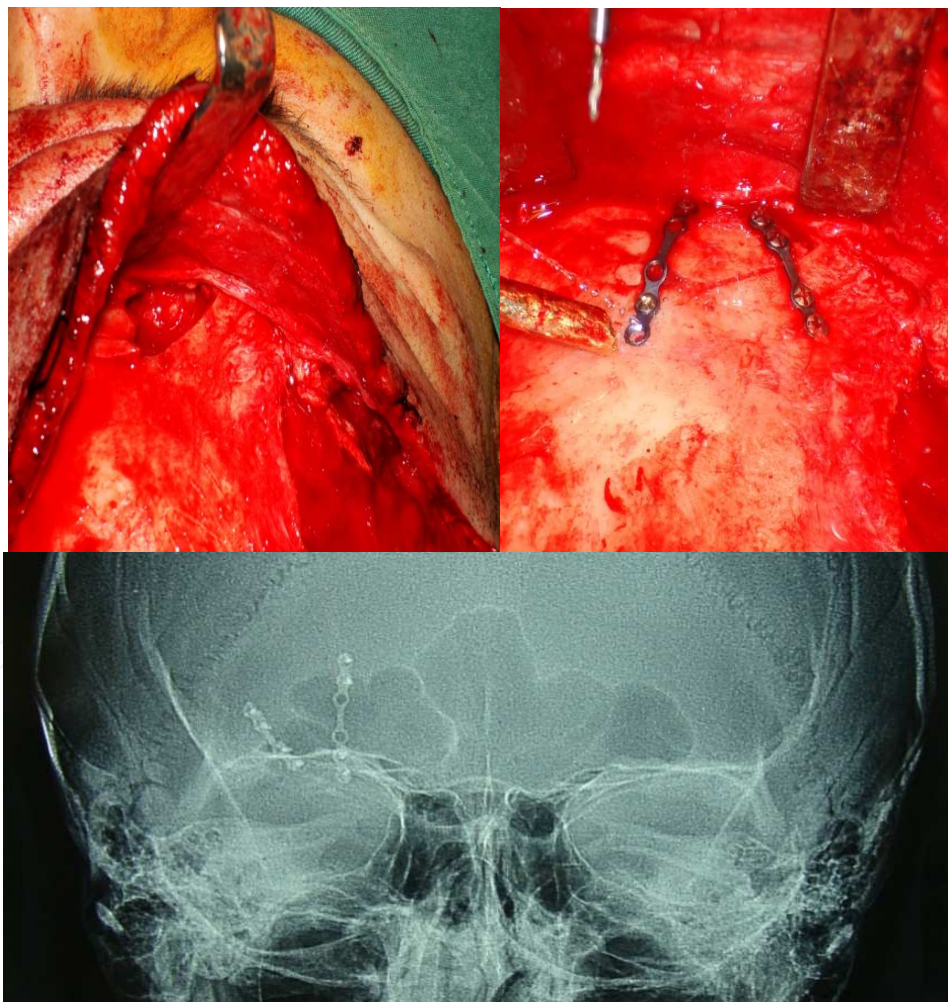


Figure 4. Left: Depressed fracture of the anterior table of the frontal sinus. Right: The fracture fragments are reduced and fixated by plates. Below: The postoperative radiograph of the patient.

materials, such as methyl methacrylate or even hydroxyapatite cements, is to be discouraged because of the risk of infection secondary to communication with the sinus floor [21].

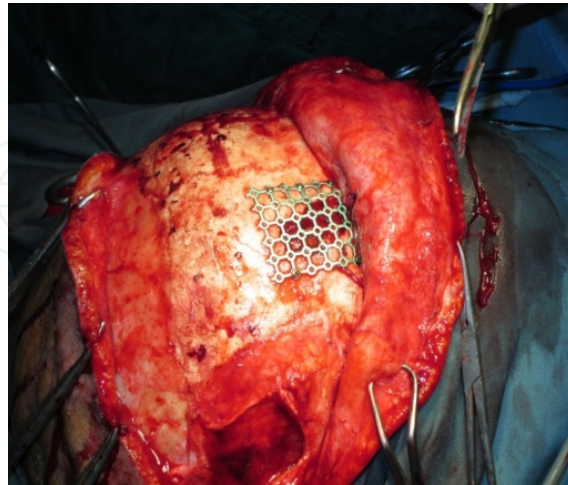


Figure 5. The severely comminuted anterior table is repaired with a titanium mesh



Figure 6. Split calvarial graft can be used for the repair of the severely comminuted anterior table

9. Fractures involving the nasofrontal duct

The anterior table fractures do not damage the nasofrontal duct unless there are concomitant nasal-orbital-ethmoidal complex or supraorbital fractures which extend into the sinus floor. A patent nasofrontal communication is necessary for the normal function of the frontal sinus. Therefore, treatment must either reestablish the communication or eliminate the sinus as a functional unit. If only one duct is injured, removal of the intersinus septum will allow mucus from the injured sinus to make its way to the uninjured side. Reconstruction of the duct requires

long-term tenting (Figure 7) and mucosal flaps. However, in unilateral and bilateral nasofrontal duct injuries, obliteration of the frontal sinus is preferred. The procedure involves the removal of all mucous membrane and the inner cortical lining of the sinus and obliteration of the nasofrontal duct and the sinus. Mucocele formation is possible if the mucosa is inadequately removed during obliteration.

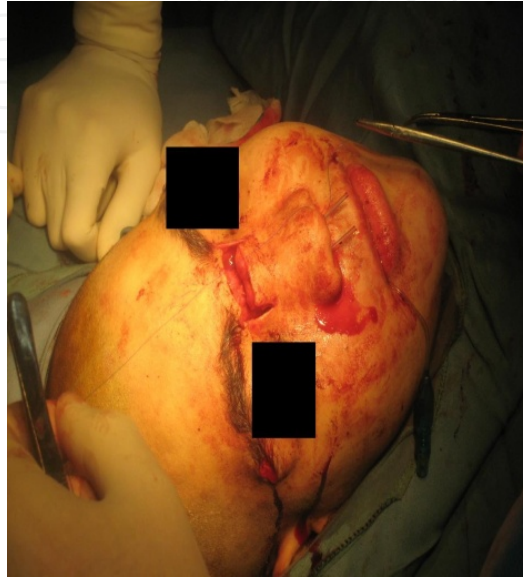


Figure 7. The frontal sinus approached with an open sky incision for reconstruction of the naso-frontal duct via stenting technique

10. Posterior table fracture

Extremely high-velocity injury may result in comminution of the posterior table with dural tearing. If this happens, the intracranial contents become in direct communication with nasal mucosa. In this setting, management principles are careful mucosal removal, nasofrontal duct occlusion and cranialization of the frontal sinus. The neurosurgeon repairs any associated intracranial injuries. The frontal lobes are then allowed to expand into the space where the frontal sinus once existed.

11. Frontal sinus obliteration

Obliteration of the sinus is performed by the use of various materials, such as fat, muscle, bone or hydroxyapatite. Meticulous removal of the entire mucosal lining is the most important element in successful frontal sinus obliteration. Permanent occlusion of frontal recess and complete obliteration of the sinus are essential in avoiding recurrence of infections and preventing possible complications [22].

Indications for frontal sinus obliteration include failure of endoscopic approaches to adequately communicate frontal sinus with the nasal cavity, loss of anterior bony table of the frontal sinus, severe fractures of floor of the frontal sinus and benign tumors [23]. The standard bicoronal incision is performed through the galea. The pericranium is incised as far posteriorly as possible, and a subperiosteal dissection is carried up to the supraorbital rim, preserving the supratrochlear and supraorbital neurovascular bundles. The frontal sinus is outlined. The anterior bony table is then removed. Sinus mucosa is meticulously exenterated with a periosteal elevator, and the interior of the sinus is carefully drilled with a medium-sized diamond burr. Nasofrontal ducts are then plugged with temporoparietal fascia and muscle. Obliteration of the frontal sinus is then performed with the previously mentioned materials (Figure 8). The anterior table plate is then replaced and plated.

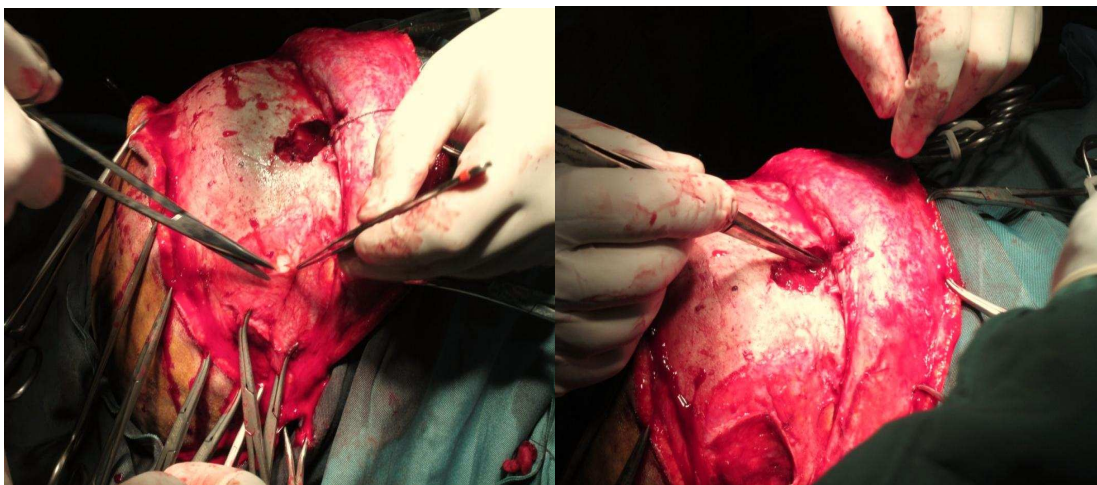


Figure 8. Left: Part of the temporalis muscle is excised for frontal sinus obliteration. Right: The frontal sinus is obliterated with muscle.

12. Frontal sinus cranialization

The primary indication for cranializing the frontal sinus is severe traumatic injury of the frontal sinus, with involvement of both the anterior and the posterior tables. Obliteration of the frontal sinus is an option in some cases but the loss of a substantial portion of the posterior table bone places the survival of a fat graft necessary for obliteration in doubt and makes cranialization more appropriate [24]. The presence of cerebrospinal fluid (CSF) rhinorrhea, the need for neurosurgical intervention, or simply an expectation of inadequate follow-up are all factors that may guide one towards cranialization. The approach to frontal sinus is performed via a bicoronal incision. Once access to the posterior table has been achieved, it is removed carefully in pieces with a rongeur. Larger pieces are saved for possible use replacing defects in the anterior table. Small overhangs at the periphery of the sinus should be smoothed completely, using a cutting burr. The end result of the removal of the posterior table bone is the elimination

of the frontal sinus as a distinct space. This space is now encompassed within a new, larger anterior cranial fossa, with the anterior table as its anterior limit.

Once the entire posterior table has been removed, all sinus mucosa is taken out. This is done first bluntly, with a hemostat or forceps. Remnant mucosa is then eliminated using a diamond burr. Establishing a secure barrier between the cranial fossa and the nose is necessary to prevent CSF leak, meningitis, and ascending regrowth of the sinonasal mucosa. After the neurosurgery team has accomplished a watertight dural repair (Figure 9), and the bone and mucosa removal are complete, the most superior aspects of the frontal duct mucosa are elevated from the underlying bone and inverted downwards, toward the nose. The superior portions of the ducts are then packed off using bone, fascia, and muscle.

Abdominal fat harvested through a small paraumbilical incision is filled in around the dural closure, occupying intracranial dead space. Repair of the anterior table is essential for both structural and cosmetic concerns. Anatomic reductions are carried out with fixation.

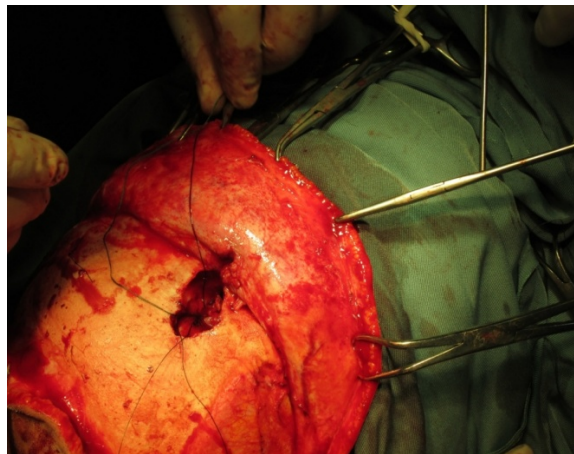


Figure 9. Water tight closure of the dura for prevention of CSF leakage

13. Flap closure

Closure of the coronal incision is performed in layers with interrupted 3-0 Vicryl stitches for the galea and deep dermis, and staples for the skin within the hairline. The skin outside the hairline is closed with interrupted 4-0 nylon stitches. Suction drains are generally avoided if immature dural closure is present. A neurosurgical head wrap is then applied.

14. Complications

Some complications of frontal sinus management relate to the surgical technique. The frontal branch of the facial nerve is vulnerable to injury during elevation of the coronal skin flap. The

result is paralysis of the ipsilateral forehead. This complication can be avoided by elevating the lateral aspects of the coronal flap in the proper plane. Too much disruption of the temporal fat pad during the lateral dissection can cause noticeable late temporal hollowing. A noticeable or widened scar from the coronal incision may develop. Other complications relate to the nature of the injury itself. CSF leak/rhinorrhea, with or without infectious consequences, may develop despite the fact that a watertight closure of the dura is performed. Management typically involves revision surgery, although nasal packing, bed rest, and CSF decompression via lumbar drain may be helpful adjuncts.

Appropriate management of meningitis relies on early recognition of signs, such as mental status changes, fever, and nuchal rigidity. When meningitis is detected, broad-spectrum antibiotics with CSF penetration should be employed empirically, with adjustments based on the subsequent cultures. A noticeable contour defect is always a possibility in the management of frontal sinus trauma. Meticulous reduction and fixation of all bone fragments and the appropriate use of bone grafts, titanium mesh, and bone cements are critically important for avoiding this complication.

The formation of a frontal mucocele, which may progress to mucopyocele, frontal bone osteomyelitis or endbrain abscess, are well-known complications of frontal sinus fractures.

15. Conclusion

The appropriate treatment of frontal sinus fractures is a controversial issue. Frontal sinus fractures represent only a small percentage of patients that require the evaluation by a comprehensive trauma service. The majority of patients will also present with concomitant facial fractures. A functional sinus can be preserved in the majority of patients, regardless of the degree of displacement, depending on the status of the nasofrontal duct, the amount of posterior table comminution, and the presence of significant neurologic injury or dural injuries. Frontal sinus obliteration is not a major component in the treatment of patients. The most important factor when treating a patient is to establish a secure barrier between the cranial fossa and the nose to prevent CSF leak, meningitis, and ascending regrowth of the sinonasal mucosa.

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